Ultrasound

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Introduction:-

Ultrasound is the modality that is used for a number of purposes including diagnosis, destruction of tissues and therapy.

Diagnostic ultrasound is used for imaging the fetus during pregnancy.

Destructive ultrasound is used to produce extreme tissue hyperthermia which has been demonstrated to have tumoricidal effects in cancer patients.

Therapeutic ultrasound is most widely used modalities in physiotherapy department .

It has been used as a valuable tool in rehabilitation of many different injuries, to stimulate the repair of soft tissue injuries and to relieve pain. It has been traditionally classified as a deep heating modality and used to elevate tissue temperature.

Ultrasound is not strictly electrotherapy because it is a mechanical vibration. It has sometimes been described as micro-massage.

The meaning of ultra is beyond or extreme. Sound is defined as the periodic mechanical disturbance of an elastic medium such as air.

Ultrasound refers to mechanical vibrations which are essentially the same as sound waves but of a higher frequency. Such waves are beyond the range of human hearing and therefore also be called ultrasonic.

Frequency of Ultrasound:-

Several different therapies are employed in range from 0.5 to 5 MHz. Majority of ultrasound generators are set at a frequency of 1 MHz, although there are ultrasound units that are set at a frequency of 3 MHz.Ultrasonic energy generated at 1 MHz is transmitted through the more superficial tissue and absorbed primarily in the deeper tissues at depths of 3 to 5 cm.

A 1 MHz frequency is most useful in individuals with a high percentage of cutaneous body fat and whenever the desired effects are in the deeper structures.

3 MHz, the energy is absorbed in the more superficial tissues with a depth of penetration between 1 and 2 cm.

Properties of Waves

Sonic waves are a series of mechanical compression and rarefactions in the direction of travel of the wave, hence they are called longitudinal waves.

They can occur in solids, liquids and gases and are due to regular compression and separation of molecules. The passage of these waves of compression through matter is, of course, invisible because it is the molecules that vibrate about their average position as a result of the sonic wave.

As sound waves pass through any material, their energy is dissipated or attenuated. Sometimes all the energy is absorbed at once. Sometimes the sound wave passes with almost no loss.

The velocity of a wave is the speed at which the wave moves through the medium, and it varies depending upon the physical nature of the medium. Sound waves will pass more rapidly through material in which the molecules are closed together, thus their velocity is higher in solids and liquids than in gases. The velocities of sound in some media are:

Air 344 m/s

Water 1410 m/s

Muscle 1540 m/s

Bone 3500 m/s

Production of Ultrasound:-

Ultrasound can be produced by following ways:-

For production of Ultrasound, machine a vibrating source with a frequency of one million cycles per second is needed. This is achieved by using either a quartz or a barium titanate or a lead zirconateor nickel-cobalt ferrite crystal. These crystals deform when subjected to a varying potential difference, this is called piezoelectric effect.

The basic components of ultrasonic apparatus are:-

There is a source of high frequency current, which is conveyed by a coaxial cable to a transducer circuit or treatment head or applicator or sound head. Inside the

transducer circuit high frequency current is applied to the crystal being fused to the metal front plate of the treatment head. Any change in the shape of the crystal cause a movement of the metal front plate which in turn produces ultrasonic waves.

Coupling Media

Ultrasonic waves are not transmitted by air, thus some couplant which does transmit them must be interposed between the treatment head (transducer) and the patient's skin. Unfortunately, no couplant affords perfect transmission and only a percentage of

the original intensity is transmitted to the patient. Even most efficient couplant reduces the applied dose by a quarter.

Air (zero transmission) will infact reflect the ultrasound beam back into the treatment head and this could set-up standing wave which might damage the crystal. Consequently, the treatment head is never left switched on when not in contact with a transmitting medium.

Some coupling medias and their efficiency of transmission are:-

1. Aquasonic gel 72.6%
2. Glycerol 67%
3. Distilled water 59%
4. Liquid paraffin 19%
5. Petroleum jelly 0%
6. Air 0%

Characteristics of a Coupling Media

1. An acoustic impedance similar to the tissue
2. High transmissivity for ultrasound

3. High viscosity

4. Low suspectibility to bubble formation

5. A chemically inactive nature

6. A hypoallergic character

7. Relative sterility

8. Cheap

9. Couplant should also act as a lubricant to allow the treatment head to move smoothly over the skin.

Techniques and methods of application

Preparation of Patient

Skin should be washed and hairs should be removed. The nature of the treatment, need for a couplant and stability of the area are all needs to be explained to the patient. The duration of the treatment as well as any particular cooperation required is indicated.

Examination and Testing

Skin surface to be treated should be inspected; inflammatory skin conditions should be avoided.

Testing the Apparatus

Prior to any treatment it is sensible to check that there is an output from the machine.

This can be done by placing the treatment head just below the water surface in a suitable container and observing the disturbance (ripples) which appears.The apparatus should be on and off with the treatment head below the water. This, and similar methods, only indicate the presence of an output but to quantity it, a radiation. Balance should be used regularly.

Preparation of the Part to be Relaxed

The couplant should be applied to the skin surface.

Setting Up

The patient should be in a comfortable position as skill is needed to apply efficient ultrasound therapy, ensuring close contact, appropriate movement and correct angle of the transducer at all times.

The treatment head is placed on the skin before the output is turned on.

This is to avoid damage to the transducer which can occur if the energy is reflected back into the transducer. Some machines have a monitoring system. If the ultrasound energy reaching the tissues becomes much less than the set intensity, the output is greatly reduced, the timer stops and the operation is alerted in some way.

Instructions and Warnings

The patient is asked to keep the part still and relaxed and to report if any increase of pain or other sensations immediately.

Application :-

The treatment head is moved continuously over the surface while even pressure is maintained in order to iron out irregularities in the sonic field.

The emitting surface must be kept parallel to the skin surface to reduce reflection and pressed sufficiently firmly to exclude any air.

The rate of movement must be slow enough to allow the tissues to deform and thus remain in complete contact with rigid treatment head but fast enough to prevent ‘hot spots’ developing when using a high intensity treatment.

The pattern of movement can be a series of overlapping parallel strokes, circles or figures of eight.

Termination

The intensity is returned to zero, either manually or automatically before the transducer is removed from the water bath or tissue contact. The skin is cleaned of couplant or dried. The transducer should be cleaned after each use with a noncorrosive, nonabrasive antiseptic lotion.

Techniques of Application

Direct contact Method

If the surface to be treated is fairly regular then a coupling medium is applied to the skin in order to eliminate air between the skin and the treatment head and transmit the ultrasonic beam from the treatment head to the tissues.

The treatment head is moved in small concentric circles over the skin in order to avoid concentration at any one point, keeping the whole of the front plate in contact with the patient.

This technique is suitable for areas up to three times the size of the treatment head. Large area should be divided and each area treated separately. The size of the area and its exact location should be specified on the treatment head.

Water Bath Method

When direct contact is not possible because of irregular shape of part or because of tenderness, a water bath may be used. As the part to be treated is immersed in water this can only reasonably be applied to the hand, ankle and foot.

A water bath filled with degassed water is used if possible. Ordinary tap water presents the problem that gas bubbles dissociate out from the water, accumulate on the patient skin and the treatment head, and reflect the US beam. If tap water has to be used then the gas bubbles must be wiped from these surfaces frequently.

The patient is seated and part is put in water of a comfortable temperature in such a position that it is suitably supported.

The treatment head is placed in the water and held 1 cm from the skin and moved in small concentric

circles, keeping the front parallel to the skin surface to reduce reflection to a minimum.

If the patient’s hand is to be immersed in the bath while the application is active, care should be taken to minimize exposure to any reflected or scattered ultrasound. This can be done by wearing a dry knitted glove inside a water-proof rubber or plastic glove.

Water Bag Method

Another method of applying ultrasound therapy to irregular surface which cannot conventionally be placed in a water bath is treated with a plastic or rubber bag filled with water forming a water cushion between the treatment head and the skin.Rubber bag filled with degassed water can be used. All visible air bubbles should be squeezed out before knotting the neck of the bag to seal it. A coupling medium has to be placed both between the rubber bag and skin and between the rubber bag and the treatment head to eliminate any air.

The bag placed on irregular surface is then held with the help of patient or others.

Treatment head pressed firmly on to the bag so that a layer of water about 1 cm thick separates it from the surface (body).

The treatment head is then moved over the surface of the bag. It does, however present problems in terms of attenuation as many more interfaces have to be crossed by the ultrasound and rubber absorbs much of ultrasonic energy. To minimize the problem thin balloons are more satisfactory because these are thin, cheap and easy to use.

Parameters of Ultrasound

1. Mode
2. Frequency
3. Intensity
4. Duration of treatment.

1. **Mode**

Continuous mode produces more heat so it is used for musculoskeletal conditions such as muscular spasm, joint stiffness, pain, etc.

Pulsed mode produces less heat so it is used for soft tissue repair, e.g. tendinitis.

2. **Frequency**

Attenuation increases with increase in frequency effectively lower frequency penetrate further.

1. Ultrasonic 3 MHz—superficial tissue
2. Ultrasonic 0.75 to 1 MHz—penetrate deeply.

Intensity

Intensity applied is according to the nature of the lesion.

For acute and immediate post-traumatic: 0.1 to 0.25 W/cm2

For chronic and scar tissue: 0.25 to 1 W/cm2

Duration of Treatment

Amount of energy depends on intensity and duration of treatment.

Size of area determine the treatment time.

1–2 minutes for every cm2

Maximum — 8 minutes

Average — 5 minutes

Physiological Effects of Ultrasound

Following ultrasonic therapy the physiological changes that take place are as follows:

Thermal Effects

As the ultrasound waves are absorbed by the tissues they are converted into heat.

Uses of Thermal Effects

The local rise in temperature could be used to accelerate healing. The extensibility of collagen is increased by rise in temperature and so stretching of scars or adhesions is easier following ultrasound. The thermal effect may also help reducing pain.

Cavitation

This is the oscillatory activity of highly compressible bodies within the tissues such as gas or vapor filled voids.

Cavitation may be stable or unstable cavitation.

Stable cavitation:-

Stable cavitation occurs when bubbles oscillate to and fro within the ultrasonic pressure waves but remain intact. It is not dangerous and could be of benefit as it modifies the ultrasonic beam in such a way as to cause microstreaming.

Microstreaming is the unidirectional movement of fluids along the boundaries of the cell. Due to microstreaming, permeability of cell membrane and direction of movement of molecules into the cells is influenced.

Unstable or Transient Cavitation:-

This occurs when the volume of the bubbles change rapidly and then collapse. It is potentially dangerous to the tissues as the collapse of the bubbles cause a great local rise in temperature.

It is avoided by moving the treatment head (to prevent

standing waves) using a low intensity and using a high frequency.

Mechanical Effect or Micromassage

This occurs where the longitudinal compression waves of the ultrasound beam produces compression and rarefaction of cells, and affect the movement of tissue fluid in interstitial spaces. This can help in reducing edema. Combined with the thermal effect the extensibility of scars and adhesions could be affected in such a way to make stretching them easier. It is also possible that the mechanical effect could help reduce pain.